THE OCCURRENCE OF PHYLLOCLADUS ASPLENIIFOLIUS (LABILL.) HOOK.F. IN VICTORIA, PRIOR TO 1100 B.P.

by

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SUMMARY

Evidence is described for the occurrence of *Phyllocladus* prior to 23,000 B.P.‡ in the Dandenong Ranges, and from 9670 B.P. until nearly 1100 B.P. in western Victoria. The dates when this conifer died out in the mainland vegetation of Victoria are deduced from the level at which the pollen disappears from pollen profiles obtained from peat sediments that have accumulated in volcanic crater lakes and valley bogs. The distinctive pollen of *Phyllocladus* has not been identified in the present atmospheric pollen rain on the mainland.

INTRODUCTION

The present paper is concerned with studies of *Phyllocladus* pollen from late Quaternary deposits in the Dandenong Ranges and western Victoria. *Phyllocladus*, a conifer in the family Podocarpaceae, is not known in the extant flora of Victoria or from elsewhere on the Australian mainland. However, fossil wood (*Phyllocladoxylon annulatus* Patton, 1958), leaves (*Phyllocladus asplenioides* Ett., 1888; *P. simplex* Deane, 1904; *P. morwellensis* Deane, 1925) and pollen (*Phyllocladus palaeogenicus* Cookson and Pike, 1954) provide evidence that the genus was present in Victoria and adjacent states during the Lower Tertiary.

Fossil stumps of *Phyllocladus*, identified by H.D. Ingle, have been found in buried soil developed on Lower Pliocene marine rocks and sealed off by basalt (Gill, 1964) near Hamilton, Victoria. The age of these stumps is thought by Gill to be of Upper Pliocene to Pleistocene age. *Phyllocladus* fossils of Tertiary age are known from elsewhere in Australia (e.g. Kemp, 1978). However there is no published account of fossil *Phyllocladus* material in sediments of younger age, and hitherto no evidence to indicate when the genus died out on the mainland.

Today, the genus *Phyllocladus* is represented in Australia by only one species, *P. aspleniifolius* (Labill.) Hook.f. (*P. rhomboidalis* Rich.). This is a tree up to ten metres high, found in the temperate rainforest and wet sclerophyll forests of Tasmania. The six other species of *Phyllocladus* occur outside Australia, in New Zealand and Malaysia (Borneo, New Guinea, Philippines and Moluccas).

POLLEN MORPHOLOGY AND REPRESENTATION

Plate 1 shows fossil and reference *Phyllocladus* pollen grains that were photographed following the methods of Samuelson (1965). The fossil grains described herein were found in the Dandenong Ranges and western Victoria. The surface features of these fossil *Phyllocladus* pollen grains were similar to those of living *P. aspleniifolius* (Labill.) Hook.f., *P. hypophyllus* Hook.f. and *P. glaucus* Carr. The average length to breadth ratio of the body of the fossil grains (i.e. not including the bladders) most closely matches that for *P. aspleniifolius* (the Tasmanian species) and *P. alpinus* (from New Zealand); see Table 1. From these diagnostic features we believe the Victorian Quaternary pollen grains to be those of *P. aspleniifolius*.

Whereas most of the fossil pollen found had expanded, with bladders diverging from

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‡B.P. = Before Present, i.e. before 1952 anno domini.

Muelleria 4 (3): 277-284 (1980).

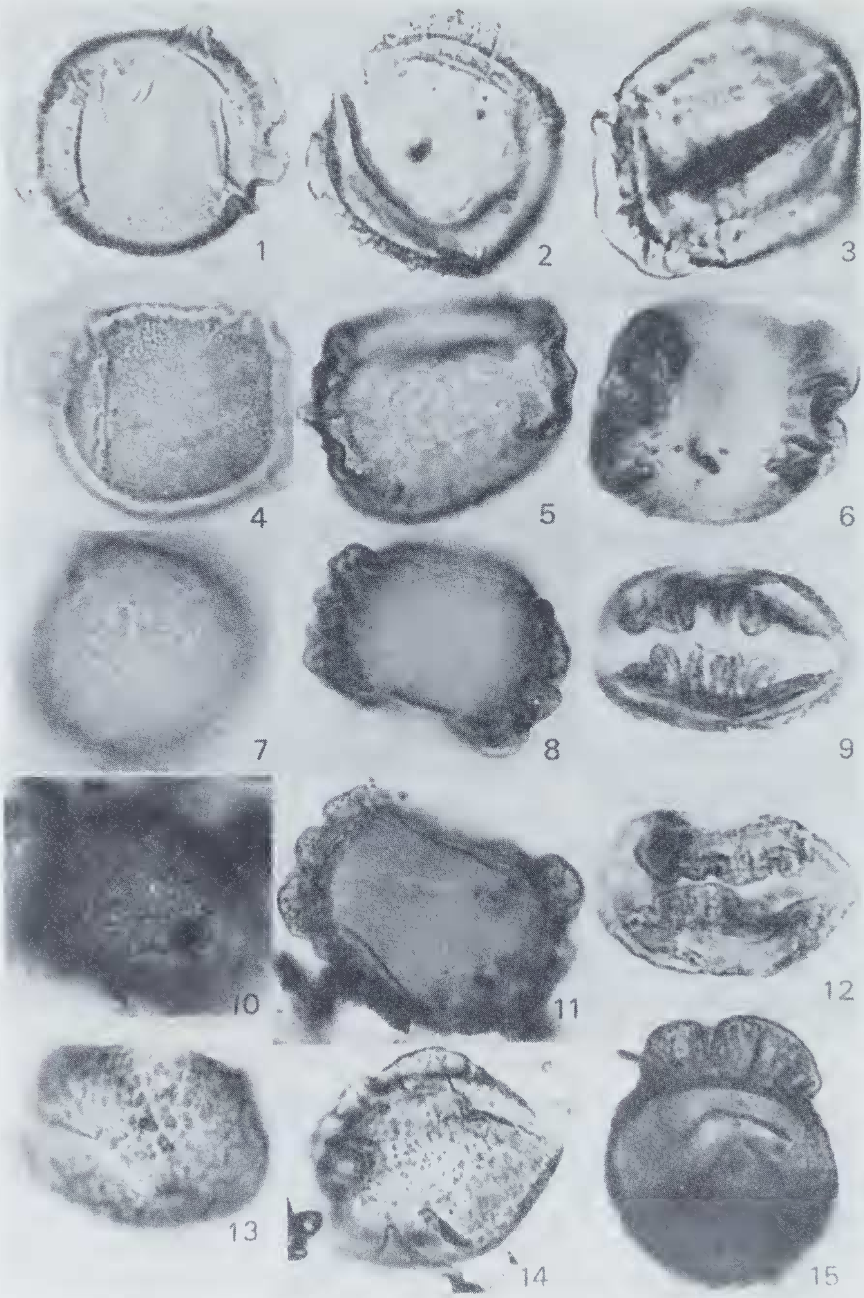

PLATE 1

1. *Phyllocladus alpinus* Hook.f. New Zealand. 2 — *P. trichomanoides* Don, New Zealand. 3 — *P. hypophyllus* Hook.f., Malesia. 4 — *P. alpinus* showing surface pattern. 5 — *P. glaucus* Carr, New Zealand, showing distal surface pattern and bladders. 6 — *P. aspleniifolius* (Labill.) Hook.f., Tasmania. 7 — *P. aspleniifolius* showing the pattern of the proximal surface. 8 — *P. aspleniifolius* Tasmania; pollen grains with this type of morphology are not as common as 9 — *P. aspleniifolius* Tasmania. 10, 11 and 15 — *Phyllocladus aspleniifolius* from peat (nekron mud) in L. Keilambete. 12 — *P. aspleniifolius* from 20-20.5 cm depth in Sherbrooke Forest core. 13 — Surface pattern of *P. aspleniifolius*, Sherbrooke Forest core, 23-23.5 cm. 14 — *P. aspleniifolius* from 21-21.5 cm depth, Sherbrooke Forest. 15 — see 10 above.

Species	Locality	Number of pollen grains measured	Average length µm	Average breadth µm	Length: breadth ratio
fossil *Phyllocladus*	Vic.	5	40.7	31.5	1.29
P. aspleniifolius (Labill.) Hook.f.	Tas.	25	29.8	23.6	1.26
P. alpinus Hook.f.	N.Z.	25	40.5	30.7	1.32
P. trichomanoides Don	N.Z.	25	39.5	32.3	1.22
P. glaucus Carr	N.Z.	11	32.4	22.9	1.41
P. hypophyllus Hook.f.	Malaysia	25	30.1	16.5	1.82
P. major Pilger	N.G.	Pollen not studied			

Table 1. Length : breadth ratios of *Phyllocladus* pollen.

the body of the grain (e.g. Plate 1: 8, 11), a few grains (e.g. Plate 1: 12) had the bladders folded inwards towards each other. In reference slides prepared from living *Phyllocladus aspleniifolius* pollen, both types of grain were present but the latter form was always the most common.

The transport and representation of *Phyllocladus aspleniifolius* pollen in Australia has not been studied in any detail. Macphail and Jackson (1978) show values around 1-2% of the modern regional pollen rain around Lake Tiberias in Tasmania. In this case the source was most likely the extensive stands of *Nothofagus cunninghamii* rainforest about 50 km to the south and south-east of the site. *Nothofagus* pollen was present in values of 2-6%. Hope (1978) reported values of 0-2% of both *Phyllocladus* and *Nothofagus* pollen on Hunter Island also at some 50 km from the nearest extensive stands of rainforest.

In contrast modern pollen rain studies in the New Zealand region (Moar, 1969, 1970, 1971; Dodson, 1976; Pocknall, 1978) show much higher representation of *Phyllocladus* pollen at similar and greater distances from source vegetation than in the case for the Australian examples. This is most likely due to a combination of factors including possibly higher pollen production of New Zealand *Phyllocladus* species and the relatively low total pollen production of vegetation of some vegetation types on offshore islands around New Zealand (see Dodson, 1976).

To gain some insight into the contemporary pollen rain in the vicinity of Lake Gnotuk, water samples were taken in 1967 at various depths in the lake and the pollen identified. *Nothofagus* pollen was present, in quantities less than 1% of the total pollen, but no *Phyllocladus* pollen was found. Howard and Hope (1970) have examined peat from *Nothofagus* forest on Wilsons Promontory. There they found that *Nothofagus cunninghamii* accounted for some 50-60% of the pollen present, but they did not record *Phyllocladus* pollen. Similarly Dodson (1977) found no evidence of *Phyllocladus* pollen in the modern pollen rain of Lake Leake in South Australia. From uppermost samples of other published Victorian pollen diagrams (Hope, 1974; Ladd, 1978 & 1979) it appears that *Phyllocladus* pollen is not a component of the modern pollen rain on the southern portion of the Australian mainland.

QUATERNARY OCCURRENCE

Towards the headwaters of Sherbrooke Creek in the Dandenong Ranges east of Melbourne, there are three small peat bogs (145° 21.35′ E.; 37° 52.92′ S.) upstream from the dam in Sherbrooke Forest. A 10 cm (4 inch) diameter core was taken with percussion drilling tools through the deepest part and the sediments were analysed for pollen.

Lake Keilambete (142° 52′ E.; 38° 12′ S.) and Lake Elingamite (143° 0.3′ E.; 38° 21.3′ S.) are two volcanic crater lakes (maars) in the Western District of Victoria. Both lakes were formed during the volcanic activity that began in the late Tertiary and continued through to the Holocene (Ollier and Joyce, 1964). Three cores, one from the centre and one offshore in L. Keilambete, and one from the centre of L. Elingamite, were taken in March 1970, with the aid of a Mackereth corer. Fossil pollen was extracted from these cores using the standard techniques described by Faegri and Iversen (1964).

Phyllocladus pollen (Plate 1) and *Nothofagus cunninghamii* pollen grains were found in highly organic peat (nekron mud) and volcanic ash sediments in Lakes Keilambete and Elingamite, and the peaty silt from Sherbrooke Forest. The levels of their occurrence in the cores and their frequences, relative to the total number of pollen and spores, are listed in Table 2.

In Sherbrooke Forest, *Phyllocladus* pollen occurs no higher in the peat than 51.0-52.0 cm below the surface. A radiocarbon date (1-4613) of 22,870 ± 690 B.P. was obtained from peat (at 47.0-49.5 cm) immediately above this level, and indicates the terminal date before which *Phyllocladus* became extinct in the Dandenong Ranges.

Locality	Radiocarbon date (B.P.)	Sediment type	Level (cm) depth from top of core	*Phyllo-cladus* %	*Notho-fagus* %
Lake Keilambete		Peat	50	—	0.10
		Peat	60	—	0.06
		Peat	90	—	0.28
		Dolomite	95-105		
	765 ± 135	Peat	110	—	0.18
		Peat	120	0.09	0.09
		Peat	170	0.12	—
		Peat	180	0.10	—
		Peat	210	0.08	0.23
		Peat	220	0.11	—
		Peat	250	—	0.06
		Peat	260	—	0.07
		Peat	270	0.08	0.03
	4930 ± 200	Peat	280	—	0.09
		Peat	290	—	0.09
		Peat	320	0.05	0.21
		Peat	330	0.07	0.07
		Peat	340	0.10	0.19
		Peat	360	0.10	0.10
		Peat	370	0.05	—
		Peat	380	0.09	0.09
		Peat	390	—	0.16
		Peat	400	0.07	—
		Peat	410	0.16	—
		Peat	420	—	—
		Peat	430	0.04	—
		Peat	450	0.11	—
		Peat	460	—	0.11
		Peat	470	0.11	—
	9670 ± 135	Peat	480	—	—
		Peaty Volcanic Ash	493	0.09	—
		Volcanic Ash	500	—	—
Lake Elingamite		Peat	0-4		
		Volcanic Ash	5	—	0.11
		Volc. Ash	10	0.07	0.67
		Volc. Ash	20	—	0.69
		Volc. Ash	30	—	0.49
		Volc. Ash	40	0.34	—
		Volc. Ash	50	—	0.41
	9380 ± 140	Peat	60	0.11	0.11
		Peat	70	—	0.16
Sherbrooke Forest		Peat	0.0-51.0	—	—
	22870 ± 690	Peat	47.0-49.5	—	—
		Peat	51.0-52.0	0.10	0.40
		Peat	53.5-54.5	0.01	0.09
		Peat	56.0-57.0	—	2.00
		Peat	57.5-60.0	0.10	1.50

Table 2. Relative frequencies of fossil *Phyllocladus* and *Nothofagus* pollen in Lake Keilambete, Lake Elingamite and Sherbrooke Forest.

In Lake Elingamite, the *Phyllocladus* pollen was contained in volcanic ash deposited in standing fresh water, and in the peat beneath the ash. Only 4 cm of undated peat is found overlying the volcanic ash in this core, but the top of the peat that underlies the volcanic ash has been dated at 9380 ± 140 B.P. (I-6224).

In Lake Keilambete the *Phyllocladus* pollen occurs in peat overlying volcanic ash. The base of this peat at its contact with the ash has been dated (I-6226) at 9670 ± 135 B.P. The peat, with a dolomite band, is approximately 480 cm thick, and the *Phyllocladus* pollen is found from the base of the peat to within 120 cm from the top of the peat; that is 365 cm above the top of the volcanic ash. From radiocarbon dates (I-5244) 4930 ± 200 B.P. and (I-5245) 765 ± 135 B.P. from the 280 cm and 104-110 cm levels respectively, it seems reasonable to date the intermediate level of 120 cm at approximately 1100 B.P.

It is evident (Dodson, 1974a) that conditions from 1100 to 765 B.P. were becoming increasingly dry. The level of the lake water fell and became increasingly saline until a bed of dolomite (95-105 cm below the top of the peat) was formed from 765 to about 450 B.P. The pollen in the peat above the dolomite indicates that the climate once more became wetter. A careful search however, has failed to demonstrate the presence of *Phyllocladus* in this uppermost peat, although *Nothofagus* pollen continues in similar frequencies to the surface levels (Dodson, 1974a).

The occurrence of very low (less than 1%) and roughly equal amounts of both *Phyllocladus aspleniifolius* and *Nothofagus cunninghamii* pollen in the sediments of Lakes Keilambete and Elingamite, means that either pollen was carried there over long distances from forests in cool wet areas, or that these species were represented by small numbers of plants in the vicinity of the crater lakes. The pollen diagrams from Lakes Elingamite and Keilamabete (Dodson 1971, 1974a) show that the bulk of the local pollen produced at that time came from Poaceae, with small numbers of *Eucalyptus* and *Casuarina*, indicative of open grassland with few trees. This is not the type of community in which *Nothofagus* or *Phyllocladus* are found today, and it seems improbable that plants from these taxa were growing any closer to the lakes than the Otway Ranges, due to the lack of suitable habitats.

CLIMATE

Meteorological data published by Davies (1965), Bureau of Meteorology (1968, 1975) and Linforth (1977) provides sufficient resolution for circumscribing the temperature and rainfall requirements of *Phyllocladus aspleniifolius* as follows: a mean annual rainfall in the range of 1500-2500 mm; mean monthly temperatures in January of 12-16°C and in July of 3.5-7°C.

On the mainland of Victoria areas that approach these bioclimatic conditions can be found today in the Dandenong Ranges, near Mt. Baw Baw, Mt. Donna Buang, Lake Mountain, Mount Torbreck, and in the Otway Region between Lavers Hill and Tanybryn. In each case the annual rainfall is sufficient but the mean January temperatures are one or two degrees too high. At Tanjil Bren, O'Shannassy and the Black Spur with mean July temperatures in the range 4-5°C, the annual range in temperature may be too great for *Phyllocladus* to survive even if it were introduced there.

At Sherbrooke in the Dandenong Ranges the present annual rainfall is 1262 mm. The mean monthly temperatures are: for January 18°C, July 6.8°C. For Zeehan on the west coast of Tasmania where *Phyllocladus* thrives with *Nothofagus* the mean annual rainfall is 2444 mm, mean January temperature is 14.2°C and mean July temperature is 6.8°C.

Using the presence of *Phyllocladus* as a basis for selecting localities for comparison of climates then it follows that the climate of the Dandenong Ranges prior to 23,000 B.P. could have been comparable to the present climate of Zeehan. The mean annual rainfall in the Dandenong Ranges has therefore decreased by comparison to that in 23,000 B.P. by some 1200 mm, the January mean temperature has risen by nearly 4°C, and the July mean temperature has not changed.

However, the presence of fossil *Podocarpus alpina* with the *Phyllocladus* pollen in the Sherbrooke Dam site means that comparisons of climate would be more appropriate with localities such as Lake St. Clair, where the mean annual rainfall is 1514 mm, mean monthly January temperature is 12.7°C and the July mean temperature is 3.45°C. This comparison indicates a climatic change in the Dandenong Ranges since 23,000 B.P. of a 250 mm decrease in annual rainfall, a rise of 5°C in the mean temperature for January, and a rise of 3.3°C in the mean July temperature.

DISCUSSION

Phyllocladus aspleniifolius occurs today in association with the cool wet *Nothofagus cunninghamii* forests of Tasmania (Busby and Bridgewater, 1977). In Victoria, *Nothofagus cunninghamii* occurs in cool wet forest communities and is restricted to Gippsland, central eastern Victoria, Wilsons Promontory, and the Otway Ranges. The Otway Ranges is the nearest (65 km SE) of these sites to the Western District lakes in which the fossil pollen was found.

The Sherbrooke Forest peat in the Dandenong Ranges contains fossil *Phyllocladus* pollen, only in the lowermost 10 cm of peat in the core. The radiocarbon date of roughly 23,000 B.P. dates the layer immediately above the *Phyllocladus* pollen and indicates the approximate date at which *Phyllocladus* died out in the Dandenong Ranges.

In Lake Elingamite, *Phyllocladus* pollen was present in the peat, prior to the eruption in 9380 B.P. ± 140. The volcanic ash sediments were deposited in water, and although they are not suitable for radiocarbon dating they contained *Phyllocladus* pollen. The last volcanic eruption in the area of the Western District was about 9500 B.P. and it is clear that *Phyllocladus* was present prior to the volcanic period and was not affected by the eruption.

The uppermost level at which *Phyllocladus* was recorded in Lake Keilambete was 120 cm at a date of approximately 1100 B.P. The more or less continuous occurrence of *Phyllocladus* pollen in the Keilambete sediments from the ash layer to the 120 cm level in conjunction with the radiocarbon dates, establishes the presence of the species from 9670 ± 135 B.P. until 1100 B.P. in the vicinity of the western districts of Victoria. *Phyllocladus* pollen has also been found in south-eastern South Australia (Dodson, 1974b) but the most recent occurrence is around 1950 B.P. These data suggest the possibility of a climatic explanation for the synchronous extinction of *Phyllocladus aspleniifolius* in western Victoria.

Dolomitic carbonate beds, in the peat from the centre of Lake Keilambete, have been studied in great detail by Dodson (1974a) and shown to have formed when the water levels were falling and close to drying out. Conditions were certainly drier than at present. The peat immediately underlying the dolomitic bed in the centre of Lake Keilambete was radiocarbon dated at 765 ± 135 B.P. (I-5245). This suggests that conditions were becoming progressively drier until around 750 B.P. after which time they became progressively wetter up to the early 19th century levels first observed by white settlers. Since that time they have been falling (Churchill et al., 1978).

Similar and approximately synchronous water level changes have been described from changes in local pollen and sediments from Lake Leake in nearby south-eastern South Australia (Dodson, 1974b) and from ratios between *Eucalyptus diversicolor* and *E. calophylla* pollen from Holocene peat deposits in Western Australia (Churchill, 1966 & 1968). It is reasonable to suggest that increasingly dry conditions from 1450 B.P. to 750 B.P. were responsible for the final extinction, by 1100 B.P. of *Phyllocladus* in western Victoria. The *Nothofagus cunninghamii* rainforest in the region undoubtedly underwent a considerable reduction over the same period but this remains to be documented by pollen analysis and dating of sediments closer to these forests than the Western District's volcanic crater lakes.

Studies from eastern Victoria (Hope, 1974; Ladd, 1978 & 1979) show essentially no change in the Holocene apart from a wetter period between about 8000 B.P. and 3000 B.P. Rainforest communities however show relative stability since that time and this could indicate that over the last 3000 years there has been a change in the factors which control the relative amounts of moisture distributed in different parts of Victoria.

It is important to record in this context, the occurrence and more recent extinction of *Phyllocladus aspleniifolius* from King Island, in Bass Strait, since 1945. *Phyllocladus* is known to have been present on King Island at 37,000 B.P. (Jennings, 1959) and in more recent time until the end of World War II. After this a soldier settlement scheme cleared the few surviving stands on the east coast. Seedlings that germinated since then have all failed to survive in the regrowth scrub that now dominates these sites. It is more than twenty years since the last *Phyllocladus* seedlings were seen there — in a deep gully between Grassy Mine and Mt. Stanley (Willis, pers. comm.).

CONCLUSIONS

Whereas the fossil evidence indicates that both *Phyllocladus* and *Nothofagus* were once widespread elements of the Tertiary floras of southern Australia, conditions later became relatively marginal. In western Victoria *Phyllocladus aspleniifolius* pollen is reliably dated in sediments as recent as 1100 to 750 B.P. but has not been found in younger sediments examined. The disappearance of *Phyllocladus* from the mainland corresponds with a period of increasing dryness that lasted from around 3000 B.P. and culminated around 750 to 450 B.P. in western Victoria. Small pockets of the species that had survived on King Island in Bass Strait until the arrival of European man were killed off by about 1950.

Phyllocladus aspleniifolius in Australia now survives only in the wind-sheltered, well-watered rainforests of Tasmania.

Bioclimatic comparisons suggest that prior to 23,000 B.P. in the Dandenong Ranges, the rainfall was 250-1200 mm higher than at present; the mean January temperatures were 4-5°C lower and the mean July temperature was some 0-3.3°C cooler than today.

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